Stimson (L. A.)

BACTERIA

AND THEIR

INFLUENCE UPON THE ORIGIN AND DEVELOPMENT

OF

SEPTIC COMPLICATIONS OF WOUNDS.

BY

L. A. STIMSON, M. D.,
NEW YORK.

WOOD PRIZE ESSAY OF THE ALUMNI ASSOCIATION OF BELLEVUE HOSPITAL MEDICAL COLLEGE, 1875.

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FIG. 1. Coccos: *a*, gliacoccos; *b*, free micrococcos; *c*, streptococcos (of Billroth), "vibrio:" *d*, spirillum, from putrefying organic solution.

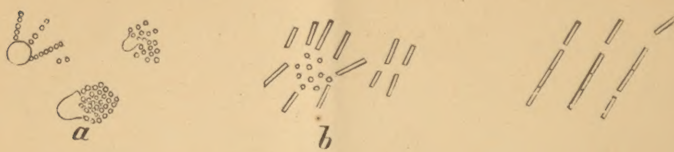

FIG. 2. *a*, Germinative spores opening; *b*. the contained coccos lengthening into bacteria; *c*, scission of bacteria and escape of one joint as actually observed (Billroth).

FIG. 3. Ascococcos: *a*, with thin wall, one is broken; *b*, husks (Billroth).

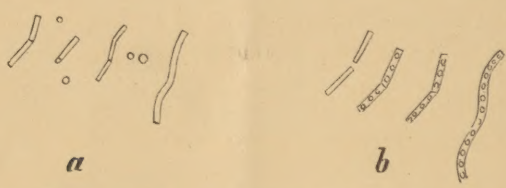

FIG. 4. *a*, Ordinary bacteria as seen with a power of about 200 diameters; *b*, the same after addition of tincture of fuchsine.

FIG. 5. Development of *Ascococcos parvus* (green mould), under a leaking faucet (Billroth).

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BACTERIA AND THEIR INFLUENCE UPON THE ORIGIN AND DEVELOPMENT OF SEPTIC COMPLICATIONS OF WOUNDS.

"Il s'agit ici de la pénétration de substances coagulables d'origine animale ou végétale en voie de putréfaction, de principes résultant de leur décomposition isomérique qui sont entrainés par la vapeur d'eau en suspension dans l'atmosphère. . . ."—Charles Robin, p. 239.

Living organisms, microscopical in size, of the simplest, most elementary nature, and moving freely in different liquids, have been known to observers for nearly two hundred years. Scientific classification and description were long impossible on account of the meagre facilities furnished by the microscopes of the last century, but during the last fifty years the means of observation have been so much improved, and the number of observers has been so great, that the advance in our knowledge of microscopical organisms compares favorably with that in other branches in science. This advance has been greatly stimulated by a tendency to see in low vegetable organisms the exciting cause of many diseases, and the supporters of the theory of "Animate Pathology" have increased, by their attempts to classify these organisms according to their supposed pathological qualities, a confusion in the nomenclature which has existed almost from the beginning, and is none the less to be regretted, although it is easily explained by the great difficulties in the way of accurate observation, study, and description.

To-day we are all familiar with the names *bacteria* and *vibrio*, and associate with them small microscopical bodies, round, oval, or rod-like and jointed, varying in length from 0.0005 mm. to 0.01 mm., and found especially in putrefying vegetable and animal infusions. The term *bacteria* is in general use in France and Germany to indicate all organisms of

this kind; the term *vibrio* has performed the same service in England, but is now giving way to the former. When the words are used in a narrower sense, *bacteria* denotes stiff, rod-like bodies, single or jointed, montionless or endowed with an oscillating movement in place; while *vibrio* is applied to those which have an undulating, sinuous motion, and move rapidly across the field of the microscope. All these forms are now almost universally considered to be vegetables, and placed among the algæ, in the family *Oscillatoria*.[1]

The earliest recorded observations of any of the varieties were made in 1684, by Leeuwenhoek ("Anat. et Contemp.," p. 38, quoted by Dujardin). He found in his dejections during a slight illness microscopical bodies, which from his description were supposed by Ehrenberg and Dujardin to be identical with their "vibrio rugula" and "vibrio bacillus," two of the largest varieties. In Leeuwenhoek's "Select Works," translated by Samuel Hoole, London, 1800, a description and drawings are given of similar bodies found in the matter picked from between his teeth, and in vinegar. In the eighteenth century Müller classified the forms then known, and in 1838 Ehrenberg (Infusionsthierchen) made the first complete list. This was slightly modified three years later by Dujardin ("Histoire des Zoöphytes," 1841), and has since been constantly used as a standard of comparison, verification, and reference. As may be inferred from the titles of their works, both these authors supposed these organisms to be animals, and, therefore, did not include in their lists some well-known vegetable forms which we now place there, and which were described by Kützing ("Phycologia Generalis," 1843) among the algæ in the family *Palmellæ*, and have been recently placed by Bastian ("Beginnings of Life," 1872) among the amœbæ. I refer to the ascococcos of Billroth and some of the zooglœa forms of Cohn. The third classification was made by Cohn in 1873 ("Beiträge zur Biologie der Pflanzen," vol. ii.), and

[1] During the last few months, Robin says, the opinion has turned in favor of placing them among the mushrooms, of which they have to be considered a new, hitherto unclassified species. The arguments in favor of this view are the general lack of color in the spores and their growth in water. The cocci then would be the spores, and the bacteria the mycelium or the "filaments."

the fourth by Billroth in 1874 ("Ueber Coccobacteria Septica."

Ehrenberg's classification is as follows: He places all the forms in one family, *Vibrionida*, the fourth family of the class *Polygastrica*. He divides this family into five groups or species, and ten varieties:

Species I., *Bacterium:* Variety 1. B. triloculare; 2. B. enchelys; 3. B. punctum.

Species II., *Vibrio:* Variety 4. V. lineola; 5. V. tremulans; 6. V. subtilis; 7. V. rugula; 8. V. prolifer; 9. V. bacillus.

Species III., *Spirochæta:* Variety 10. S. plicatilis.

Species IV., *Spirillum:* Variety 11. S. tenue; 12. S. undula; 13. S. volutans.

Species V., *Spirodiscus:* Variety 14. S. fulvus.

He described the first species as a stiff-jointed rod, *in catenam filiformen rigidulam abiens*, the second as a flexible serpent-like chain, *anguis instar flexuosam*, the third as a flexible, the fourth as a stiff filiform spiral or tortuous chain, the fifth coiled on itself in the form of a disk. Those small round or oval forms now described as micrococcus he placed in the family of monads, *Monas*.

Dujardin cut out Species V. because it had been seen only once by Ehrenberg, during a journey into Siberia, and incompletely observed, added Species IV. to Species III., and reduced the number of varieties to ten, throwing out B. triloculare and B. enchelys, consolidating some and dividing up others.

Cohn groups all under one name, and divides as follows:

Bacteria.—Tribus I., *Sphærobacteria* (Ball bacteria): Variety 1, Micrococcus.

Tribus II., *Microbacteria* (Rod bacteria): Variety 2, Bacterium, subdivided into B. termo and B. lineola.

Tribus III., *Desmobacteria* (Thread bacteria): Variety 3, Bacillus; Variety 4, Vibrio.

Tribus IV., *Spirobacteria* (Spiral bacteria): Variety 5, Spirillum (of Ehrenberg); Variety 6, Spirochæte (of Ehrenberg).

Billroth makes no claim to a complete botanical classifica-

tion. He deals principally with the forms which are found in animal infusions, and in the body during disease or after death. But, while he does not attempt to describe all the varieties, he gives a complete history of those which he has observed, tracing the whole cycle of their development, and showing so close a genetic relationship between them that it seems probable future investigation will show the others to be included in it. He considers all the forms combinations of spherical and cylindrical bodies, representing only different periods of development. His nomenclature and classification being based upon this opinion, he groups all under the name *coccobacteria* (*κόκκος*, a berry, and *βακτηρία*, a little rod), and gives to the different forms names which are compounds of these two with words denoting the number, size, and arrangement of the component parts; micro-, meso-, and mega-, signifying small, medium, and large; mono- and diplo-, single and double; strepto-, in chains; glia- (*γλία*, glue), in groups; asco-, in bags; and petalo-, in plates. This classification is simple and clear, for each name has the great advantage of describing accurately the form to which it is applied.

A detailed description of all the varieties is not needed here. The terms *bacteria* and *vibrio* have been already explained; there remain two others, *bacteridia* (French, bactéridies; German, bacteridien) and *micrococcus*[1] or *microzyma*, which are constantly met with in recent pathological works. The former was applied by Davaine to long immovable forms of bacteria found by him in the blood of animals affected with anthrax; they belong in Variety 3, bacillus, of Cohn, while the latter is applied to the innumerable round or oval forms found in the tissues, secretions, or blood, of persons suffering from septic diseases, and in putrefying liquids.

Natural History of Bacteria.—Bacteria are cells lacking chlorophyl, of spherical, oblong, or cylindrical form, which multiply by scission and vegetate either singly or in groups (Cohn, *loc. cit.*, page 136). They possess a cell-wall and colorless nitrogenized contents, protoplasm, which refracts the

[1] *Micrococcus*, first employed by Hallier and adopted by Cohn, but with a different signification, makes the plural micrococci. Micrococcos, as used by Billroth, has no plural.

light more strongly than water, is contractile, and by its contractility occasions the movements of the plants. The existence of the cell-wall can be sometimes made out with the aid of high powers, and may be easily demonstrated by its resistance to caustic potash and ammonia (Cohn).

Both Billroth and Cohn testify that there is no genetic relationship between bacteria and any of the yeast-plants, including saccharomyces, the alcoholic ferment, or indeed any of the fungi and moulds. Billroth says (*loc. cit.*, page 49) that wherever any luxuriant yeast vegetation except oidium lactis is growing rapidly, the elements of coccobacteria septica do not flourish. Cohn claims that the resemblance between the alcoholic ferment and the torula form of sphærobacteria (mesococcos of Billroth) is merely an external one, and that all reliable observations controvert the opinion held by Hallier, Karsten, Huxley, and others, that these two belong in one and the same circle of development. As to the absence of genetic relationship between bacteria and fungi, his views are supported also by Burdon-Sanderson (Appendix to Thirteenth Report of Medical Officer of the Privy Council), and are founded partly on these two facts, that Pasteur's liquid exposed to the air developed mould (penicillium, etc.) and no bacteria, and when impregnated with a drop of water containing bacteria and placed in a tube corked with cotton it developed bacteria and no mould. They are also distinguished from the typical fungus by the absence of mycelium, and for this reason were classified by Naegeli as *schizomycetes.*

Development.—It is not necessary to discuss the possible origin of these organisms by spontaneous generation. Although that view is held by some, it is so manifestly incompatible with the observations of the authors above mentioned and the complete developmental history as described by Billroth, that it needs only to be mentioned here.

Billroth was the first to discover the nature of the germinative spores (Dauersporen), although they were described and figured by Cohn. These germinative spores, which are glistening, dark-bordered globules, develop in their interior masses of coccos which are set free by the bursting of the envelope, but are maintained in contact with it for some time by the

presence of *glia*, a mucous or gelatinous substance which is supposed by Billroth to be secreted from the wall of the coccos, and by Cohn to be the result of the softening of that wall. This description can be easily verified; I have found, in putrid animal infusions exposed to the air during three weeks in summer, these spores in all conditions, from those forming within bacteria, as will be described hereafter, to the empty shell. The coccos may multiply by lengthening and scission, or they may lengthen into bacteria and gradually free themselves from the enveloping glia by their own active motions, so that the external portion of the masses enveloping the germinative spores is seen to be formed almost entirely of bacteria in active motion. This scission ordinarily occurs in one direction only, the two pieces are held together by the glia, and each divides again and again, forming longer or shorter rosary-like chains, *streptococcos* (στρεπτός, chain). When the scission takes place in both directions we have the square sarcina forms. The bacteria also lengthen and divide transversely, forming the well-known jointed bacteria, *diplobacteria*, with which all are familiar.

The scission may take place so rapidly that each bacterium forms a streptococcos, and when the glia is very abundant the scission of the coccos goes on within it indefinitely, producing the large masses known as *zooglœa*. If the glia is very tenacious, it may form a thin or thick perfectly clear and transparent membrane about the mass, *ascococcos* (ἀσκός, a bag), which sometimes shows amœboid movements. After a time this membrane bursts, the coccos escape, and the empty husk is found at the bottom of the vessel. It may be mentioned here that Billroth was fortunate enough on two occasions to see with Hartnack's No. 15 immersion objective a micrococcos lengthen and divide, and the two parts separate from one another in the course of half an hour.

The final fate of all bacteria presents three varieties: 1. The plasma may leave the husk in the form of a finely-granular sterile mucus. 2. It may break up rapidly into micrococcos within the husk, expanding it considerably and forming a variety of ascococcos. 3. It may contract into one or more glistening, dark-outlined bodies which are the germinative

spores with which the description began, and which, after a certain period of repose, may again germinate. *The vitality of the latter is not destroyed by freezing, boiling-heat, or by drying*, and these spores carried about in the air are undoubtedly the principal agents in the production of coccobacteria. Billroth had some which germinated after having been kept eight years. This is the only form which withstands drying; the coccos and bacteria do not, and this fact explains the failure of many impregnations with dried bacteria. The germinative spores, having fallen to the bottom of the liquid, were not included in the portions taken for the experiments.

Motions.—The isolated coccos possess only a motion which cannot be distinguished from the common molecular movement of very small, inert portions of matter, the so-called Brownian movement. Tiegel says (*Virchow's Archiv*, July, 1874) that, if the liquid in which they are contained is evaporated by a moderate heat and then fresh liquid added, they do not regain their motion, and one or two fine granules appear in their interior. When, however, they remain united in chains (streptococcos), they appear to have a sinuous, serpent-like motion which carries them, sometimes with great rapidity, across the field of the microscope. This undulatory motion is denied by Cohn, who considers its appearance due to a real rotary motion about the long axis. This opinion is certainly correct in the case of the larger spiral forms, but I have been unable to verify it in the smaller, straighter forms, say 0.003 mm. in length, whose extreme tenuity makes their examination very difficult and uncertain. Progression is made in either direction, and the large spiral ones often move forward and backward across the field almost with the regularity of a pendulum; sometimes one end attaches itself to the covering-glass or to some large object in the water, and the other swings slowly backward and forward, or the whole revolves rapidly about its long axis without change of place. The same motions are observed in the microbacteria chains, but the larger ones are generally motionless, and the isolated bacteria show only an oscillatory motion without change of place. No locomotory or motion-producing organ has been discovered except upon one of the spiral forms, Spirillum volutans, on

each end of which Cohn found a fine, whip-like thread. The motions seem to be dependent upon the fluidity of the medium and the presence of oxygen, and are much hindered by the glia; they persist at a temperature as low as 35°, grow slow at 130°, and cease at 140° Fahr. (Billroth).

Nourishment.—For their nourishment bacteria need carbon, which they can assimilate from any carbon compound (except carbonic acid), nitrogen, which they can take from ammonia, urea, and probably also from nitric acid, and certain of the elements of the ashes of ordinary yeast, of which the most desirable are phosphate of potash, sulphate of magnesia, and nitrate of lime or chloride of calcium (Cohn). All the experimental liquids in ordinary use are composed in accordance with this. Pasteur's liquid has been found to be better fitted for the nourishment of bacteria when it contains no sugar.[1] Bacteria resemble green plants in this, that they assimilate the nitrogen contained in their cells in the form of ammonia compounds, which animals cannot do; on the other hand, they differ from green plants and resemble animals in this, that they cannot take carbon from carbonic acid, but only from organic compounds of carbon, especially the hydro-carbons and their derivatives (Cohn).

Functions.—Bacteria are not parasites; they do not live upon the materials intended for the nourishment of the tissues in which they are found, and cause the death of these tissues by starvation, but they are saprophytes,[2] and probably live upon some of the elements of the substance itself by the withdrawal of which new chemical combinations of the others are caused. Putrefaction is a correlative phenomenon of life, because it occurs only when a microscopical vegetable organism nourishes itself and multiplies at the expense of a part of the

[1] Cohn used the following modification of Pasteur's: Distilled water, 100 parts; nitrate of ammonia, 1 part; ash-elements, about 1 part. He recommends also Mayer's normal solution of nutritive mineral salts:

Phosphate of potash	0.1 gramme.
Crystallized sulphate of magnesia . .	0.1 "
Tribasic phosphate of chalk . . .	0.01 "
Distilled water	20 cub. ctms.

[2] Saprophyte, σαπρὸς, putrid, and φυτὸν, plant.

putrescible substance. This organism is the bacterium, or at least some of its forms or varieties, for many authors agree with Cohn that putridity is excited only by Bacterium termo, a form which Cohn describes as having a length of 0.002–0.003 mm., found often in pairs and possessing a tremulous motion; it is the microbacterium of Billroth. Cohn (*loc. cit.*, pages 169, 170) says they multiply as long as the putrid process lasts, and disappear as soon as it ceases; that he is convinced B. termo is the ferment of putrefaction, as yeast is the ferment of alcoholic fermentation, and that no putrefaction can begin without it, or progress without its multiplication. Other bacteria may aid in the process, but their *rôle* is secondary, and B. termo is the primary exciter of putrefaction, *the only saprogenic ferment.* Organic nitrogenized substances never putrefy by themselves, but only when they are decomposed by the vitality and multiplication of bacteria. "This is not only supported by microscopical researches, which show that B. termo is constant in putrefaction, but comes with convincing certainty from an unprejudiced consideration of the innumerable researches into *generatio æquivoca*, especially those of the last few years. These show that putrefaction of an organic nitrogenized substance cannot occur if bacteria are kept away from it, after those that were already present have been killed; that it begins as soon as even the smallest number of bacteria are added, and advances at the same rate as that in which they increase, and stops when exposed to any one of the influences which prevent the multiplication of, or kill, bacteria. On the other hand, bacteria multiply only as long as they find material capable of putrefaction."[1] Cohn carries this physiological distinction still further, and divides his ' ball-bacteria," micrococcus, in which no morphological differences can be seen, into three groups, according to their supposed power to produce pigment, fermentation, or disease,

[1] It may be proper to mention that, while this (Pasteur's) theory of fermentation or putrefaction is generally accepted to-day, the followers of Liebig deny its entire correctness, and maintain that "certain non-living albuminoid substances are also capable of acting as ferments" (Bastian, "Beginnings of Life," vol. i., p. 405). Billroth attaches much importance to a saying of Hoppe-Seyler: "Fermentation is possible without organisms, but not definite fermentations without definite organisms."

and again subdivides the third group according to the different diseases in which the micrococcus is found (M. vaccinæ, M. diphtheriticus, M. septicus). That these plants do not possess in themselves the power of causing disease, but that, at the most, they act only as carriers of contagion, and therefore that the above classification is unjustifiable, will be shown in the second part of this article. The coccobacteria then have but three well-marked functions: 1. Some of them produce certain pigments (Cohn); 2. Some cause special fermentation (Pasteur); 3. Some excite putrefaction. They may also aid mechanically in the transport of various contagions, and, by their presence and rapid multiplication in the body during the existence of an abnormal condition of the blood, juices, or tissues, may mechanically impede normal physiological processes, and perhaps render the increase of an already existing poison more rapid and fatal.

Distribution.—Bacteria exist in one form or another in all water (Cohn), most animal tissues (Billroth), and in the air. In the latter they are found only in the form of germinative spores, the other forms not being able to support the absence of moisture. Their presence in the healthy living body has been often affirmed and denied, but has recently been demonstrated beyond cavil by Billroth, and still more recently by Tiegel (*Virchow's Archiv*, vol. lx., July, 1874). Burdon-Sanderson's denial of their presence (quoted by Cohn) was based upon the fact that the addition of small portions of fresh meat and blood from animals in full health did not cause cloudiness of Pasteur's liquid; Rindfleisch (*Virchow's Archiv*, vol. liv.) got the same result and drew the same conclusion, having used rain-water in place of Pasteur's liquid. Billroth denies the correctness of the inference, because it is now well known that the strongly acid, sugary Pasteur's liquid is not favorable for the development of bacteria, particularly of those found in the alkaline blood, and that as all liquids are not favorable for the growth of all bacteria, and as the latter are not universally present in forms capable of further development, Rindfleisch's single experiment cannot weigh against the very numerous and carefully-conducted ones which have demonstrated the presence of these organisms.

In the air spores are present, but apparently so few in number, and so light, that they do not alter the artificial nutritive liquids, and only very slowly infusions of animal and vegetable tissues (Cohn). All observers agree that they are found at times in all kinds of water. Rindfleisch thinks they are sometimes absent from rain-water; but Cohn found them in the moisture condensed upon the interior of a bell-glass placed over an open dish of water. Of course, they may have been deposited from the air, but the question of their origin does not affect the fact of their universal presence. Recent investigations have shown them to exist in large quantities on the walls of old hospitals (Nepveu, in *Gazette Médicale*, June 27, 1874). The spores, which float in the air, or are deposited upon exposed surfaces, remain inert and innocuous until the conditions necessary to their development are supplied, among which moisture is the chief. Cohn maintains that 140° Fahr. is sufficient to kill bacteria and bacteria-spores, and that when any are found to have survived that temperature, or even 212°, it is probably because the liquid containing them has been unevenly heated. Billroth, on the other hand, says that the germinative spore can withstand more than 212° Fahr. Both agree that all the forms withstand very low degrees of temperature (even zero Fahr., Cohn), but that at the freezing-point, and probably even at a somewhat higher temperature, they lose their power of motion and multiplication, and consequently their power of causing fermentation and decomposition, but regain it as soon as the temperature is raised.

To recapitulate: Bacteria are microscopical vegetable organisms of two main varieties: 1. Round or oval cells 0.0005–0.0010 mm. in diameter, single or arranged in lines or groups (sphærobacteria, micrococcus, Cohn: micrococcos, streptococcos, Billroth). 2. Cylindrical cells 0.002–0.003 mm. long, single, or arranged in lines (bacteria of both authors). There is no genetic relationship between them and ordinary mould and fungus. They are found in the air, water, and most animal and vegetable tissues. They are saprophytes, not parasites, and are unable in themselves to cause any of the infectious diseases.

What influence have bacteria upon the origin and development of septic complications of wounds?

The frequency and gravity of these complications have made their etiology, pathology, and treatment, one of the most important and interesting of all surgical problems, and the scanty success that has hitherto attended all prophylactic and remedial measures shows that the problem, in part at least, is still unsolved. Their cause was first supposed to lie in the absorption of the pus of the wound through the open mouths of the severed vessels; then in poisoning of the blood by pus formed in the interior of the vessels by phlebitis (Hunter), or by thrombosis (Darcet, 1842, popularized ten or fifteen years later by Virchow); then in the absorption of putrid matter from the surface of the wound (Gosselin);[1] in the formation of a virus in the secretions of the wound and its penetration into the circulation; and, finally, in the introduction of bacteria.

The poisonous effects of putrid matter have long been known; in 1815 Ortila (quoted by Piorry) killed dogs by inoculation of putrid blood, bile, and fragments of tissue; and in 1827 Hamont (quoted by Coze and Feltz) killed a horse by means of injections of putrid pus taken from a gangrenous abscess, and a second horse with blood taken from the first—the first dying on the fourth, the second on the fifth, day. Piorry, in an article on typhohémie, written probably in 1835, gives a full and accurate account of those symptoms to which he afterward gave the name septicæmia, by which they are now known. He ascribed the disease solely to the effects of the absorption of putrid matter through the lungs, skin, intestine, or the surface of a wound, but did not attempt to discover the cause of its virulence. Panum (*Virchow's Archiv*, vol. xxv., 1862, quoting from an article of his own published April,

[1] The question of priority in discovery is always a difficult one to settle. The works which have popularized our knowledge of septicæmia have been largely German, but it seems to me clear that the possibility of absorption by granulating wounds and the marrow of bones was first demonstrated by Gosselin in 1855 ("Mémoires de la Société de Chirurgie," tome v., p. 147), and that he was the first to publish the theory that the *ensemble* of symptoms now known as septicæmia was due to the penetration into the body by such absorption of putrid matter.

1856) speaks of a non-volatile septic poison, which is insoluble in absolute alcohol, soluble in water, and not destroyed by prolonged boiling.—Robin ("Dictionnaire de Médecine") considered the virulence due to a catalytic effect produced upon the humors and tissues of the body by contact with a substance in which putrefaction had brought about an isomeric change in the fundamental "immediate principle," and he said ("Comptes Rendus de la Société de Biologie," 1863), "Putridity is not virulence; on the contrary, when it has advanced to a certain degree, it destroys virulence," a statement which is universally accepted to-day.—Bergmann ("Das putride Gift," 1868) said; "The toxic action of putrid organic substances is not due to inferior organisms, but to a diffusible nitrogenized toxic substance which resists alcohol, ether, and boiling heat, and is formed during putrefaction."

But the believers in the importance of bacteria were not idle. Mayrhofer ("Jahrbücher der Gesellschaft der Aertze in Wien," 1863), claimed that puerperal fever was due to low organisms which he called vibriones. He had observed that they appeared first in the lochia of healthy lying-in women on the fifth day after delivery, and in small quantities; but in those sick with puerperal fever they appeared immediately after delivery, and in much larger quantities. He then injected a putrid infusion of meat into the uterus of a rabbit soon after delivery, causing its death from endometritis with septicæmic symptoms. Leplat and Jaillard ("Comptes Rendus de l'Académie des Sciences," vol. lix., p. 250, 1864) made nine inoculations with putrefying animal and vegetable infusions; eight of these caused no serious symptoms. They concluded that "vibriones coming from any substance whatever cause no accidents in the animals into the blood of which they have been introduced, unless they should be accompanied by virulent agents, which latter are alone responsible for any unfortunate results which may ensue." In 1865 Coze and Feltz published a series of observations (*Gazette Médicale de Strasbourg*), which they claimed proved that the blood of animals inoculated with putrefying liquids is itself infectious; that its red corpuscles are profoundly altered, and that it contains bacteria; also, that successive inoculations of different indi-

viduals of the same kind—that is, from No. 1 to No. 2, from No. 2 to No. 3, etc.—become rapidly fatal; that the infectious ferment gains in force by its passage through the organism. In 1872 they published a book in which the results of these and later experiments were set forth. They claimed that the figured elements which they found in the blood were the active efficient agents in the poisoning. They called these elements infusoria, and said they appeared to belong rather to the genus Bacterium than Vibrio, and to be the B. punctum and B. catenula of Dujardin; they were probably the micrococcos and micro-bacteria of Billroth. The authors agreed with Pasteur that there were two phases of putrefaction, of which only the first would cause poisonous symptoms. This is another way of stating the fact which has been already mentioned, that putrefaction destroys virulence. They were also the first to find micrococcus during life in the blood of typhoid patients.

In the mean time Davaine had been studying anthrax in animals (malignant pustule in man), and had discovered *bacteridia*, which he claimed to be the toxic principle of that disease. In 1869 he had repeated and confirmed the earlier experiments of Coze and Feltz (his studies were interrupted by the war in 1870–'71), but on September 17, 1872, he read before the Académie de Médecine in Paris a report of three series of inoculations with putrid blood. The first series showed that inoculation with several drops was fatal in less than half of the cases; those with one drop of blood putrefied in the open air rarely killed, and that sometimes ten or fifteen drops were necessary. The second series comprised successive inoculations of blood from one animal to the next; it showed that $\frac{1}{100}$ to $\frac{1}{10}$ of a drop was sufficient to kill the fifth, $\frac{1}{20,000}$ to $\frac{1}{10,000}$ would kill the tenth, while for the twenty-fifth the *one-ten trillionth* part of a drop was sufficient. The third series showed that the septicæmic virus is destroyed by putrefaction. We must pass rapidly over the discussion that followed. These experiments, received with much distrust at first, were substantially verified by many observers, and the conclusions finally accepted by most were: 1. That the susceptibility to the virus varies much in different animals, rabbits being the

most susceptible. 2. Putrid blood loses its virulence as it gets older. 3. That septicæmia is a putrefaction taking place in the blood of an animal, and induced by bacteria and vibriones (*Bulletin de l'Académie de Médecine*, October 8, 1872). 4. That blood putrefied outside of the body is much less poisonous than that of an individual whose death has been caused by, or who is still suffering from, septicæmia, typhoid fever, or gangrene of the lung. 5. That the one-millionth part of a drop of such blood injected into the cellular tissue of a rabbit will cause the death of the animal in less than twenty-four hours. 6. That the poisonous quality of the blood is entirely due to the presence of bacteria. Most of the inoculations were made with blood taken from the cadaver several hours after death, and containing multitudes of bacteria. Vulpian denied that inoculations with blood taken from patients affected with typhoid fever would cause death by septicæmia, and claimed that inoculations with blood taken from the cadaver must be considered only as inoculations with putrid blood. He failed to find in blood taken during life more than a few scattered granulations (micrococcus) and bacteria. He also claimed that septicæmia produced experimentally differed from that observed in man; that the former appeared to be "a sort of internal parasitic affection, which certainly was not the case with typhoid septicæmia in man, in which the presence of inferior organisms in the blood was a variable circumstance, and unquestionably only accessory." In order to mark this distinction, he suggested for the former the name *bacterémie* (*Bulletin de l'Académie de Médecine*, second series, vol. ii., p. 420).

On April 15, 1873, Onimus reported a series of experiments, conducted under the direction of Prof. Robin, by which he claimed to have demonstrated: 1. "That virulent blood can preserve its virulence in spite of the disappearance of vibrios and bacteria. 2. That blood may contain these inferior organisms, and still not be virulent; consequently, that the virus of putrid infection is not an organized ferment, but an albuminoid substance. These conclusions were denied by Davaine and Pasteur on the ground that the absence of bacteria from the material used for the inoculations was only ap-

parent; that, although none were visible at the time, they existed nevertheless in an invisible stage of development.

All the original opponents of Davaine had now given their adhesion to his views, and this report of Onimus made little or no impression, opposed as it was by the great authority of Pasteur. The question, which had been discussed at every meeting of the Academy since September, 1872, now received much less attention; an occasional report upon it was made by those who had been specially identified with it, and by the majority it was considered to be definitively settled. In the mean time the discussions had excited a great deal of interest in all countries, and the experiments were repeated in many of the laboratories of England and Germany; an occasional article showed that the importance claimed for the bacteria was not universally admitted; and, since the publication of Billroth's work in 1874, the weight of testimony has been against them. The results of experimental pathology were subjected to the light of clinical observation, and extensive investigations were made to determine the presence or absence of bacteria in the liquids and tissues of the body during the different stages of septic diseases and after death. Of these none were more thorough than those conducted by Billroth. He found, in two hundred autopsies of all diseases, cocco-bacteria present in eighty-seven in the pericardial liquid. The longer the interval between the time of death and the examination, and the higher the temperature of the air, the more certainly were these organisms found. Although they are found in abundance during life on many of the mucous membranes, it is probable that they make their way into the tissues and circulation only through the lungs, and that they remain, especially in the blood, in the form of germs capable of development. This view is opposed by Burdon-Sanderson, and Rindfleisch, and supported by Hensen (*Archiv für microscopische Anatomie*, vol. iii.), and more recently by Klebs. It is probable that the organisms also make their way rapidly after death from the stomach and intestines, and from open wounds into the tissues.

Lewis and Cunningham (Calcutta, 1874) made seventy-three examinations of the blood, and forty-three examinations

of the mesenteric glands of dogs killed by various means, and state that the only feature common to the cases in which bacteria were found was, that a certain period of time had elapsed after death before the examination was made. The shortest was five and one-half hours. In an examination of blood taken from a dog in a state of great depression, and just before his death from the effects of intense inflammation excited by the injection, not of a putrefying organic liquid, but of ammonia into the peritoneal cavity, large quantities of bacteria were found.

Offensive rancid pus from wounds contains micrococcos chiefly, and yet the quantity is not proportionate to the intensity of the odor; and, further, as great quantities of micrococcos can be present without the coexistence of any fever, their appearance in the pus of a wound has no immediate connection with the unfavorable course of a traumatic inflammation, or with pyæmia; the pus from cavities communicating with the external air almost always contains micrococcos, and yet the patients may remain perfectly free from fever, and make good recoveries.

Billroth relates three cases of *acute closed abscesses*, which may have communicated at some earlier period with the air. The first was an abscess of the epitrochlear gland following a wound of the fingers; the pus was sweet, and contained masses of micrococcos. The second was an abscess of the scrotum following lithotomy, which contained a bloody, brown, badly-smelling pus, and no micrococcos; but he thinks the latter may have existed previously, and perished from lack of oxygen. The third was a case of osteomyelitis of the upper end of the tibia; the pus contained no coccos; but pus which formed subsequently in the knee-joint, and was removed by aspiration, was full of streptococcos, and was odorless; the fever ran high, and death followed amputation. Examination showed no organisms in the blood or inguinal glands, but the stump was infiltrated with pus containing many free micrococcos.

Inodorous, thick pus from several cases of *completely closed acute abscesses* contained no organisms, and in one case of marked septic poisoning, with œdematous phlegmon of the

thigh, following a bruise of the skin, the inodorous liquid removed by incision contained no trace of coccobacteria. This case shows that the most dangerous and extensive phlegmon with septic poisoning can occur without the aid of this vegetation. An inodorous, half-purulent extravasation of blood opened fourteen days after the accident, on account of inflammation of the parts, a metastatic abscess of the thyroid gland, and very fetid pus from a subcutaneous abscess caused by passive motion of a stiff elbow, all contained micro- and streptococcos.

Pus, freshly taken from *cold abscesses* caused by injury to bone or joint, was never found to contain coccobacteria. In a case of dissection wound followed by lymphangitis, the pus contained no coccos.[1]

In some cases of *erysipelas* he found coccobacteria in the bullæ, in others he found none.

In *ulcerative diphtheria of wounds* and *hospital gangrene*, he found large quantities of micro- and streptococcos.

Vogt (*Centralblatt*, No. 44, 1872) found crowds of micrococcos in blood taken from the skin of a pyæmic patient near the point at which amputation had been performed, and also in pus from a metastatic abscess in the wrist, while very few were found in blood taken from other parts of the same patient. Injections of the first blood into the back of a rabbit caused a large abscess, which was found to contain large quantities of micrococcos, as did also the neighboring muscles.

Wolff (*Virchow's Archiv*, December, 1873) claims that there are cases of acute pyæmia and septicæmia in which the presence of bacteria in the blood cannot be proved microscopically or experimentally, and yet the pus of the wound contains them, and inoculation with it is fatal.

In the body of a healthy animal, the development of cocco-

[1] Dr. Bergeron presented a paper to the Académie des Sciences, the 15th of February, 1875, which contained the result of the examination of the pus of eighteen closed abscesses. He found bacteria in all the hot abscesses of adults, and none in cold abscesses, or in hot ones of patients below the age of twenty-two years. Their presence was not accompanied by any serious symptoms. In a second series of examinations, not yet published, bacteria were found in the pus of a hot abscess of a boy about sixteen years old, and were absent in one or two abscesses of adults.

bacteria is very difficult if not impossible. The active movement of the blood hinders it greatly, and the vital energy of the tissues is a very serious obstacle, because the normal exchange of nutritive material is so energetic that these plants cannot check it and absorb the nourishment needed for their own growth. This is an important fact, for, according to all analogy, only by active vegetation of this plant could an alteration of the blood occur which would lead to its death. Fresh blood and pus are not favorable to the development of coccobacteria even under the most favorable conditions, and when masses of micrococcos are found in the tissues, and in pus, it is certain that some change has taken place to render the medium suitable for their nourishment; the moribund dog of Lewis and Cunningham, already mentioned, is a case in point. This change is thought by many to be due to the supply to the pus of certain materials, products of unhealthy inflammation, from the neighboring inflamed tissues. If this neighboring inflammation ceases, if the pus becomes surrounded by healthy granulations, and can flow freely away, then its alteration ceases, and so too does the vegetation of micrococcos; but if this barrier is not formed, if the inflammation continues, the alteration of the pus and the rapid vegetation of the plant react upon and increase the original inflammation, thus forming a vicious circle, which may rapidly produce the most fatal results. Experiment shows that decomposition of fresh pus rapidly follows the addition of a drop that has been already affected. The same effect is produced by the addition of a drop of a putrefying infusion of meat, or of the serum of a wound, or of urine, and this shows that the poison is produced as well outside of the body as in inflamed tissues. If the pus of an open wound has been infected from the outside, its prompt removal and extreme cleanliness of the wound for a few days may restore it to its healthy condition, and the principal danger does not lie in the ordinary spores which may fall upon the wound from the air, for they require a certain time for their development, and do not act at once as ferments, but it does lie in those which have taken up some of this virus, and which, aided probably by it, act at once as a ferment upon any pus with which they come into contact.

To this material Billroth gives the name phlogistic zymoid (ζύμη, ferment material), because it is produced by inflammation, and is capable of reproducing it in turn, and while it is not a ferment in the sense in which yeast is one, it is ferment like, *zymoid.*

A suppurating wound, then, may be poisoned by the introduction of foreign matter from without, decomposition of the pus is caused, and if the latter is not promptly removed, and the wound cleansed so as to prevent further decomposition, the granulations are destroyed and a special inflammatory process is set up in the neighboring tissue. Or this special inflammatory process may be the result of mechanical violence due to improperly-arranged bandages, or irritation and crushing of the granulations; the phlogistic material is formed and mixed with the pus, insuring its decomposition, the growth of coccobacteria and septic poisoning. In either case the presence and development of coccobacteria are not necessary to the process, and the most dangerous phlegmons may occur without the slightest trace of these organisms. Billroth gives a case in point which has been already referred to:

"A man, fifty-four years old, irritated the skin over his shin by friction against the hard edge of his boot; he continued to work for ten days, and was then compelled to take to his bed with high fever and chills; four days afterward he was brought to the hospital, apparently in collapse, with all the symptoms of intense septicæmia. A superficial scab was found on the shin of the right leg, around it the skin normal, but on the knee and entire outer half of the thigh it was very red and swollen, doughy to the touch, and without distinct fluctuation. After the patient had taken some brandy, he rallied sufficiently to allow an incision to be made along the outer part of the thigh and front of the knee. The serum mixed with pus which escaped was entirely odorless, and showed no trace of micrococcus. The patient did well until the twelfth day, when he was attacked by pneumonia and died."

Acute grave inflammation can be excited by many causes, of which crushing is the type, and this effect is produced not by putrefaction of the parts which are entirely killed, but by the chemical changes in those which are half killed, in which the circulation still goes on. A break in the skin increases the danger. Similarly, the most dangerous freezing is that which does not go on to absolute death of the tissues; and

partial obstruction of the circulation, as effected by the stitches in a wound, is far more dangerous than ligature of an artery.

So far as we know, the products of all acute inflammations are infectious in certain stages; this virulence is also shared by certain substances formed by putrefaction, but no one has yet been able to separate the poison or to describe it fully. Most writers agree that it is not destroyed by boiling heat, a fact which seems to be an additional proof that it cannot be due to the presence of vegetable organisms. Panum (*Virchow's Archiv*, July, 1874, page 348) says, "Putrid poison is formed in putrefying tissues and liquids, is a peculiar chemical substance, not composed of albuminous matter, not destroyed by heat, is soluble in water, and can be thence precipitated by means of alcohol." He thinks it is perhaps produced by the growth of bacteria, especially B. termo. He also testifies to a fact which has been already stated, that putrefactive bacteria which may make their way into the circulation of healthy men cannot continue to exist there, and can multiply only after a certain grade of decomposition after death has been reached, the appearance of which is greatly hastened by the presence of putrid poison. "But," he continues, "putrid poison with or without bacteria can make its way, especially from wounds, into the blood during life, and cause the ordinary symptoms of putrid infection, septicæmia; and there is a certain specifically pathogenic fungus, *Microsporon septicum* of Klebs, which differs from B. termo, and, when carried by the air or intentionally inoculated, is developed especially in the blood and pus, probably under the predisposing influence of the putrid poison, and seems to be able to multiply very rapidly in the blood and tissues of living bodies, and cause fever, suppuration, and inflammation, in part by the production of a special poison, and in part mechanically."

There is but little difference between this description and Billroth's, for "putrid poison," "phlogistic zymoid" must be substituted, and for "microsporon septicum," "micrococcus." Both consider the development of the plant made possible only by the presence of a predisposing poison, and both think it may be carried by the air, but, where Panum's theory re-

quires the coöperation of two processes; Billroth's requires only one; for, according to the latter, the spore may take up and "fix" the poison, so that when floating in the air it carries in itself, though not of itself, the means to render the soil upon which it falls suitable for its future growth. One of Panum's experiments deserves mention. He made a watery extract of the residue left after alcoholic extraction of the dried residue of a putrid liquid. Inoculation of a dog with this watery extract caused its death in three hours with acutest symptoms of septicæmia. Injections of the alcoholic extract had no effect (*loc. cit.*, p. 335). These experiments supplement Hiller's, and together they confirm those of Onimus which have been already mentioned. Hiller (*Centralblatt*, February, 1874) made thirty-two injections with putrid matter subjected to various processes designed to remove from it every thing except the bacteria, and got no results beyond finding masses of dead bacteria in the skin at the place of injection. Other portions of the injected liquid caused active vegetation in Pasteur's liquid. He concluded consequently that bacteria have no phlogogenic or pyrogenic influence, and that their development is possible only in material that is dead or incapable of regular exchange, and finally that septicæmia is due not to bacteria but to the absorption of the products of inflammation and decay.

The demonstration of the existence of a virus, far from solving the question of the etiology of septicæmia, only removes it a step backward. We have yet to learn the conditions of the formation of this virus both in putrefying matter and in the living, although injured, body. This is a question which, strictly speaking, is not included in the subject of this article, and can, therefore, receive only a passing mention. Pasteur's brilliant studies of fermentation, of which putrefaction is a variety, have shown that the process cannot go on without the aid of living organisms, among which the cells of vegetables and even of animals are to be classed. For instance, during the ripening of fruits alcohol is formed within them and carbonic acid is given off in considerable quantities as a result of the transformation of the sugar. In this case the ordinary alcoholic ferment is not present, and its part is performed by

the cells of the fruit. There is reason to believe that a similar function belongs to the cells of animal tissues, that all life is a fermentation,[1] and that for the vague term "vitality" or "vital action," we have to substitute another which conveys the idea of a definite chemical process.

It is easy to comprehend that among the products of putrefaction there may be one which is very deleterious to the living body when the latter has been inoculated with it, and, on the other hand, that the portions of an organism which have been injured and are living under altered conditions, such as constant pressure, mechanical or chemical irritation, or insufficient supply of blood, may cease to functionate normally and may give rise to abnormal products which are as deadly to the parent organism as is the sting of a scorpion when plunged into its own body.

This is a question for the physiologists and pathologists of the future. At present it is but an hypothesis, a "working hypothesis," a convenient form for expressing the relations between certain well-established processes, and is not yet a fact definitively acquired by science; but, as it is now under investigation by its author, perhaps the most successful experimenter of the age, we have a right to expect its speedy verification or abandonment.

The question at once arises, Why does not this acute specific inflammation spread rapidly in all cases over the whole body? Its course in the tissues is often limited by fasciæ; this is due probably to the slight diffusibility of the poison, and to the fact that it is diluted by the serous exudations and carried by them to the surface, or if absorbed it is absorbed by the lymphatics, so that the inflammation follows the course of these vessels. When this specific decomposition of pus has taken place on a wound covered with healthy granulations, the latter form a very strong barrier against infec-

[1] M. Poggiale: ". . . si la définition de M. Pasteur devait comprehendre les cellules végétales et, ainsi qu'il nous l'a annoncé, les cellules animales, la vie dans les végétaux, comme dans les animaux, ne serait qu'une fermentation universelle."

M. Pasteur: "Ce serait bien possible."

Bulletin de l'Académie de Médecine, 1875, p. 283.

tion of the underlying tissues, and time is thus afforded for proper cleansing of the wound and arrest of the process. It cannot be admitted that the leucocytes have any share in inoculation or spread of the contagion except so far as they may be able to take up and "fix" the poison, as do the vegetable organisms; upon this point nothing is known beyond the fact that occasionally leucocytes are found which seem to inclose bacteria or coccos, although the testimony of the microscope is not conclusive when its highest powers have to be employed. Of course, it is theoretically possible that the inclosed or adherent plants may have previously been in contact with and have absorbed the poison, but this is an unnecessary refinement, since the spread of the process can be easily accounted for without the aid of the pus-corpuscles.

As pus is not affected morphologically by the presence of the virus, and may have all the appearances of pus that is *bonum et laudabile*, and does not necessarily have an offensive odor, we can account for the difference of the results obtained by experimenters; and, further, as the presence of the virus in stagnant pus favors the free development of micrococcos, and is itself in turn increased thereby, we must admit the correctness to a certain extent of the observation of Klebs and others, that pus containing micrococcos is especially infectious.

In the other specific acute inflammations—diphtheria, erysipelas, hospital gangrene—this influence of the micrococcos does not differ from that which it possesses in the acute phlegmon which we have described. Its appearance is always preceded by the characteristic lesion of the affection; in the diphtheritic affection of a wound, for example, the borders become hard and infiltrated with coagulated fibrine before the appearance of more than a few isolated micrococcos in the secretions; in erysipelas, as has been already mentioned, they are sometimes absent and sometimes present in the serum of the bullæ, and this affection certainly is not dependent upon the presence of vegetable organisms; in phagedenic or hospital gangrene a stiff fibrinous infiltration always precedes the ulceration, and, while the micrococcos is very abundant on the surface, it penetrates only to a very slight depth; in phlebitis, the inflammation begins in the outer coat of the

vessel, and, after the latter has become hard and cord-like to the touch, it still remains pervious—coccobacteria have evidently nothing to do with this process; and, lastly, they are almost always absent in thrombi and small metastatic abscesses.

To conclude, the argument may be summarized as follows: Septicæmia is the name given to an adynamic condition of the organism caused by a certain alteration of the blood. This alteration is not due to a parasitic influence exerted by the rapid growth of coccobacteria, because all observations show that this plant is present in the blood of the living animal only in exceptional and rare cases, and then its presence can be proved to be due to local and exceptional causes. Moreover, clinical observation shows that the disease always has its origin in a lesion of the tissues, generally an open wound, either through inoculation from without, or through mechanical or chemical irritation of the parts; but coccobacteria are often entirely absent from these starting-points of the disease; and, secondly, are often present in the pus and secretions of wounds and abscesses, without exciting septicæmia.

Inoculations which will cause septicæmia may be made with materials coming from the acute special inflammations mentioned, or from putrefying animal liquids and infusions. Coccobacteria are almost always present in these liquids, but they may be removed, and yet the virulence of the liquid will still be preserved (*see* experiments of Onimus, Hiller, and Panum).

Coccobacteria having thus been eliminated, what remains? Only the products of putrefaction in one case, and those of inflammation in the other. Must we not, then, conclude that there is produced in the secretions of these wounds, or in the adjoining tissues, a certain product of inflammation which resembles, if it is not identical with, the poisonous principle of the products of putrefaction. The latter is known as "putrid poison;" to the former Billroth gives provisionally the name "phlogistic zymoid."

It is highly probable that this virulent substance can be taken up by vegetable forms (coccobacteria), which may then serve as carriers of contagion, and that it is very favorable to

their rapid multiplication, by which it is itself in turn very much increased in amount.

Prophylaxis and treatment.

The practical result of all these experiments and observations is to be sought in the treatment of wounds. They indicate that the acute inflammatory complications to which so many of the deaths following surgical operations are due, are induced by certain alterations in the secretions of the wound, or in the adjoining tissues, and that these alterations are due to abnormal chemical ("vital") action of the cell-elements of the tissues, itself caused by mechanical or chemical irritation of the parts, or by inoculation, and that this inoculation is effected by means of particles of this abnormal product, or by low vegetable organisms which have previously been in contact with and have absorbed it. Treatment, then, must be directed to avoid injurious mechanical and chemical action, to prevent inoculation, and to remove or destroy the poison when it has been formed.

The extent to which these indications can be met will be best learned from a description of the measures in general use. Billroth (*loc. cit.*) discusses subcutaneous wounds, treatment with caustics, attempts to get union by first intention, open treatment, immersion and irrigation, treatment of deep irregular wounds, disinfection, and antiseptics. In addition to these should be mentioned Guérin's permanent dressing of cotton-wool without attempting primary union, a mode of treatment which is now quite popular in France.

The favorable course of subcutaneous wounds is too well known to need more than a passing mention, but the application of this method is limited to comparatively few surgical operations, most fractures, and some penetrating wounds which heal on the surface by first intention. Recent investigations have not added much to our knowledge of the causes of the good results of this method. They appear to be due to the slight extent of the injury, the favorable conditions for reunion, and the exclusion of the air.

Treatment with caustics is based upon the fact that primary acute phlegmonous inflammations often occur during the first two or three days, before suppuration has fairly set in. By

producing an eschar upon it, the whole surface is protected as by a skin; and, when the eschar falls, a healthy granulating surface is left behind. To avoid too great febrile reaction, the cauterization must be superficial and applied only to wounds of moderate size. The same result may be obtained in extensive superficial injuries, such as burns of the second or third degree, by creating an artificial skin by means of various adhesive preparations, such as collodion mixed with castor-oil, gum-tragacanth, finely-powdered flour dusted over the surface, or a mixture of molasses and gum-arabic.

Union of the wound by first intention throughout its whole extent is theoretically the best way to meet all the indications, but the failures of attempts to procure this result are so frequent in all large or irregular wounds, and their consequences so disastrous, that the method is now generally abandoned in large hospitals, except for minor cuts, wounds of the face, and also, according to Billroth, after enucleation of tumors or glands which have a firm fibrous capsule. If it is attempted, great care must be taken that the stitches be not too tight, and the pressure of the bandages not too great; and, for the deeper wounds, Simpson recommends deep metallic sutures and occlusion of the arteries by acupressure, and it has also been advised that the ends of the ligatures should be attached to a long needle and carried to the surface through the neighboring tissues so as to leave the main wound unobstructed by them. The causes of the frequent failures will be mentioned under treatment of large irregular wounds. A serious complication appears during the first forty-eight hours in the form of acute phlegmonous inflammations, followed by septic poisoning, and it is always doubtful if the bad effects of the first treatment can be overcome.

The open treatment of wounds consists in free exposure of their whole surface to the air. Part of the secretions form a crust upon the surface of the wound, the rest flows away, and the wound remains odorless. The crust is dry and consequently unfavorable for the development of spores that may fall upon it; and when it comes off it discloses a healthy, granulating, perhaps partly cicatrized surface, which cannot easily be injured by contact with ferments. This is the "heal-

ing under a scab" of the English authors, of which Paget speaks so highly. Billroth says the method was first introduced in 1856 by Vézin, and that he himself adopted it in 1860, and has since employed it with the best results in amputations, resections, and after removal of many tumors. Its chief advantage is that it protects against the dangerous primary phlegmonous inflammations by allowing free escape of all the secretions, but it does not protect against erysipelas and hospital gangrene, and is useless when inflammation has once set in. If the wound is irregular and permits the accumulation of pus and secretions, there is danger of inoculation by micrococcos.

Treatment by immersion and irrigation is based upon the same principle as the preceding. Irrigation is difficult to apply, but has the great advantage of washing away all the secretions as soon as they are formed; but, when simple immersion is used, more or less pus remains adherent to the wound. In both modes of treatment primary phlegmonous inflammation rarely occurs, but if any does begin, its consequences are rendered more disastrous than ever by the tumefaction of the granulations which imprison the products of decomposition.

Deep irregular wounds, forming pockets or cavities in which the secretions may stagnate and decompose, are the most dangerous. If the wound involves normal loose cellular tissue, the confined secretions trickle back into it and cause acute inflammation, or are absorbed by the lymphatics and veins, giving rise to thrombi, which break down and cause dangerous emboli, generally of the pulmonary arteries. If the tissues are firmer, or if they have been thickened by chronic inflammation, the danger of infiltration is much less, and this is one reason why subperiosteal resection of bones results less frequently in pyæmia; similar favorable conditions exist when an inflammatory process has attacked the interior of the sheath of a tendon, or when an encapsulated tumor or gland has been removed. During the first two or three days every care must be taken to insure the removal of all the secretions; after suppuration has begun, the danger is less, and is due chiefly to the collection of pus in cavities

formed by irregular lines of union, or sometimes in the subcutaneous tissue, or between the muscles, or in the marrow of the bones. This happens about the end of the first week, and, if the complication is promptly recognized and its cause is accessible, all the new adhesions must be broken up, free incisions made into all purulent cavities and infiltrations, and the wound cleansed and allowed to lie open. In cases of deep suppuration, or those involving joints and bones, this cannot always be done, and it then becomes a problem, as difficult as it is important, to determine whether amputation shall be performed, and at what time. On this point Billroth says (*loc. cit.*, p. 227), in suppuration of the shoulder, elbow, and ankle joint, we can accomplish something by means of carefully-conducted treatment with ice; but in deep suppuration of the lower leg or of the forearm, extending along the bone, or of the thigh, or of the knee-joint, he would decide promptly upon amputation, after the complication had made steady progress for a few days. The result of amputation depends upon the extent of the general infection. If metastatic abscesses have formed, it is seldom of any avail; but if this is not the case, then, no matter how high the fever nor how frequent the chills, amputation is always to be tried.

A consideration of the source whence the infection is derived is essential to treatment by means of antiseptics or disinfectants. Practically we need not consider the possibility of infection by means of spores entering the body through the lungs or the intestines, for a general destruction of all the spores in the air and food is impossible, but against immediate inoculation of the wound much may be done by the strictest cleanliness on the part of the surgeons and attendants, and by the use of various disinfectants. We know that all coccobacteria-spores cannot grow in all liquids, and that many which fall from the air upon wounds do not vegetate because they do not find there the necessary nourishment and conditions; *and we have every reason to suppose that there is developed in hospitals, in the pus and secretions of wounds, a variety of this plant which becomes especially adapted, by this cultivation, to live upon such materials*, and from such a variety most danger is to be apprehended. Such spores could be

transported by the air, by the hands and instruments of the attendants, and by the bandages. Billroth considers this source of danger so important that he uses no sponges in operations or dressings, except in cases of ovariotomy and the like, where they cannot be dispensed with, and substitutes for them pledgets of cotton. Those which he is compelled to use he disinfects thoroughly with hydrochloric and carbolic acids.

Thorough ventilation is the only practicable means of disinfecting the air, but there is no lack of good antiseptics which may be used directly upon wounds. It is essential to their efficacy that they should be constantly in contact with every portion of the wound, and, since that is practically impossible, the use of these agents does not release the surgeon from the obligation to employ every additional means to increase the cleanliness of the wound and promote the free discharge of all its secretions.

Among the best known disinfectants the following may be mentioned:

Chlorine-water—in its concentrated form (one to ten); it is rather painful, and when diluted its application must be frequently renewed.

Iodine—a very active antiseptic, and especially useful against diphtheria and hospital gangrene; the objection to it is that the applications must be frequently renewed, and are then likely to cause acute inflammation.

Glycerine—a very useful and cleanly dressing.

Alcohol—theoretically excellent, but its rapid evaporation is a great objection. Gosselin uses it for all wounds of the head and face, to prevent suppuration, and favor union by first intention.

Camphor—only slightly soluble in water, and is not a deodorizer.

Olive-oil—useful to prevent inoculation by falling spores, but is useless after infection has taken place.

Subacetate of lead—very highly recommended; even in a very weak solution it kills bacteria, and has a slight astringent effect upon the surface of the wound, but it is not a good deodorizer.

Carbolic acid—has become very popular of late years,

Billroth thinks it is in no way superior to many others; its odor is very offensive to some, and when dissolved in oil it ruins the dressings and bedding. Salicylic acid is beginning to replace it.

We have finally to consider the cotton-wool dressing, the *pansement à l'ouate* of A. Guérin. After the operation has been completed, bleeding arrested, and the surface of the wound washed with water or some weak disinfecting solution, a large bunch of cotton-wool is placed between the lips of the wound, and the whole limb is then enveloped in a layer of cotton eight or ten inches thick, which is then bound down very firmly with roller-bandages, which are tightened on the following day, and then the dressing remains untouched for about three weeks. If the pus makes its way between the limb and the dressing, and appears after a few days at its free margin, additional bunches of cotton are placed over the edge and bound down. Clinical experience shows that patients whose wounds are dressed in this way generally remain free from fever and pain, eat and sleep well, and make good recoveries. In one case that came under my own notice, and two recently reported by M. Guérin (Académie des Sciences, March 23, 1874), removal of the dressing at the end of the third week was followed on the first or second day thereafter by severe phlegmonous complications, due, apparently, to the temporary exposure. Guérin claims that this method differs from "occlusion,' because air can pass freely through the cotton which acts only as a filter, freeing it from all spores and ferments. Pasteur says that ferments are undoubtedly present in the cotton and in the wound, but that the physical condition of the pus is rendered unfavorable for their multiplication by the absorption of its liquid portions, and he advises exposure of the cotton to a temperature of about 400° Fahr. before application as an additional precaution.[1] However that may be, the method has two evident advantages; equable temperature and complete immobility of the limb.

[1] I have had occasion to examine several of these dressings after removal and have always found living bacteria present in the more or less liquid pus which bathed the wound, even when the dressing had been perfectly successful.

It must be borne in mind that these procedures have been instituted to meet the exigencies of, and have been judged by their results in, large hospitals, especially those of Europe. The hygienic conditions found in those establishments are very unfavorable; many of the buildings were erected generations ago, and in accordance with ideas which are now universally rejected. They are found in the centre of large cities, surrounded by other buildings, their ceilings low, their beds crowded, and ventilation dependent entirely upon the will and intelligence of the nurses.

In the country and in new hospitals of improved construction attempts to get union by first intention are generally successful, and the dangerous acute primary phlegmonous inflammations, to which reference has been made, so frequently are rare.

To the efforts of the Sanitary Commission during the war of 1861–'65 is due the spread of the pavilion system of hospital construction. This consisted of groups of separate buildings of only one story, removed sufficiently from one another to allow free circulation of air, thus supplying as nearly as possible the conditions of open-air treatment; and the success of those army hospitals was so great that the principle of their construction is now generally accepted, and a large hospital has been recently built at Leipzig on this plan.

The ideal hospital is one that shall be destroyed and replaced every year or two, and, although that is practically impossible, may we not hope that the statistics of the future will show that intelligent construction of hospital buildings has at last removed the evil influence which has so long baffled the zeal, skill, and devotion of surgeons?

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